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Research Article

Effect of Cultivar and Planting Date on Soybean Response to Dicamba

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Off-target movement of dicamba has been blamed for damaging millions of hectares of soybean in the United States since registration of the herbicide for use in dicamba-resistant cotton and soybean. Understanding the effect of a low dose of dicamba on non-dicamba-resistant soybean across multiple cultivars, growth stages, and planting dates could help producers better understand the implication of current management practices on yield loss from dicamba in fields where non-dicamba-resistant soybean are grown. A field experiment was conducted in 2019 in Fayetteville and Stuttgart, Arkansas, to evaluate the impact of planting date on response of soybean to a low dose of dicamba. The hypothesis of the planting date experiment was that soybean injury and yield loss will differ depending on planting date and dicamba application timing. Additionally, an experiment was conducted in 2018 and 2019 in Fayetteville to assess whether cultivars differ in sensitivity to dicamba. The hypothesis of the cultivar experiment was that genetic differences of soybean cultivars will allow for differential tolerance to dicamba. In the cultivar experiment, "Eagle DrewSoy" was identified as having enhanced tolerance to dicamba based on reduced injury (47% at R1 and 26% at *V*3) over both experimental years and locations. Soybean height in this experiment was affected only by application timing. In the planting date experiment, planting after mid-June resulted in reduced yields from dicamba injury. Dicamba exposure reduced yield at the July planting date (61% reduction from nontreated) more severely when compared to dicamba-treated plots of other planting dates (94% average relative yield among other planting dates), indicating that the negative effects of dicamba are increasingly deleterious for soybean planted later in the growing season. Maximum injury manifestation was generally delayed at later planting dates, indicating that dicamba may have been metabolized more slowly.

1. Introduction

Selection and cross-breeding have been used to modify crops and create new cultivars with unique advantages for thousands of years; meanwhile, utilization of crops based on differing response to herbicides is a staple of modern agriculture, such as the use of herbicide-resistant cultivars. Discovery of existing cultivars with differential tolerance to herbicides could help farmers make practical decisions when faced with modern challenges such as herbicide off-target movement. For example, a study of postemergence applications of bentazon at 3.4 kg·ha^{-1} to several hundred cultivars of soybean [*Glycine max* (L.) Merr.] saw little effect to the most soybean cultivars tested; however, all plants of the cultivar "Hurrelbrink" were killed, and 10 other cultivars were extremely sensitive [1]. Research such as this proves variability in crop response to herbicides may exist across cultivars.

Herbicide off-target movement to sensitive crops at reduced rates is common. In a study focusing on off-target movement of propanil to soybean, a differential injury response was noted among soybean cultivars tested, with yield of a more highly injured cultivars also significantly reduced compared to most of the other cultivars tested [2]. Specific to synthetic auxins, as early as 1978, it was reported that soybean cultivars may differ in yield loss in response to a low rate of dicamba [3]. In this research, one cultivar did not experience yield reduction to an early-bloom-stage application of dicamba whereas four others did. The extent of injury to soybean from dicamba exposure may also differ among cultivars [4]. One study saw equal yield reductions from a dicamba application to two cultivars of non-dicamba-resistant soybean, but height reduction as a result of dicamba application varied between the cultivars [3]. Further research in differential tolerance of soybean to herbicides could help provide practical data for better management decisions via cultivar selection.

Planting date is one of the most important factors of crop production. Research into the effects of planting date in conjunction with the effect of other factors to crops, such as herbicide injury, could provide practical information for farmers when making production decisions. Planting date impacts many aspects of soybean production, including growth [5], development [6], yield [7], and even grain quality [8]. Planting date can have an impact on crop emergence, with faster emergence representative of later plantings [7]. Later-planted soybean typically experiences shorter intervals between planting and initial flowering [9]. Chen and Wiatrak [6] found that the shorter vegetative and reproductive growth stages of late-planted soybean occurred in response to increased radiation interception, such as during mid and late summer [7], whereas soybean planted earlier usually yield higher due to a longer duration of vegetative and reproductive stages [6]. Later sowing dates for soybean extend the time between *R*6 and seed maturity, and in general, later sowing dates result in lower yields, although this can vary in some depending on cultivar [7].

Yield decline from late planting is mostly due to a reduction in pod number [7] and total nodes [5]. Under longer photoperiods associated with late planting, the length of soybean vegetative and reproductive stages decreases, contributing to yield loss [8]. In addition to photoperiod, increased temperature and decreased precipitation can also influence the yield and growth of late-planted soybean [8]. Maturity group can also affect optimum planting date depending on region; for example, among soybean with maturity groups V–VIII, the optimum planting date on the Georgia Coastal Plain ranged from May to early June [9]. The optimum planting date ranges from late May to early June for soybean planted in the mid-west, upper south, and deep south [10].

Plant biomass, height, and other yield-related factors can also be impacted by late-planting soybean [11]. One study found that soybean height was reduced by 19 cm at a mid-June planting date compared to an early-May planting [5]. Later planting dates have also been shown to negatively impact the oil and protein content of soybean [8]. With the recent introduction of dicamba-resistant technology, taking into consideration the sensitivity of non-dicamba-resistant soybean to dicamba, as well as the potential for off-target movement of the herbicide, understanding the impact of management factors such as cultivar selection and planting date on sensitivity of the crop to the herbicide and the ability of the crop to recover from injury may allow growers to better understand risks and expectations when injury to soybean occurs. Therefore, field experiments were conducted to evaluate the effect of planting date and cultivar selection on soybean injury and yield in response to a low dose of dicamba.

2. Materials and Methods

2.1. General Methodology. For all experiments, the design was a randomized complete block with treatments in a split-plot arrangement with four replications. A nontreated control was included for comparison. The dicamba rate for each experiment was 2.2 g·ae·ha^{-1} or 1/256$^{\text{th}}$ of a 1*X* rate (560 g·ha^{-1}) for dicamba-resistant soybean and cotton (*Gossypium hirsutum* L.). Dicamba was applied using CO_2-pressurized backpack sprayers calibrated to deliver 140 L·ha^{-1} at 276 kPa using AIXR 110015 nozzles with a spacing of 51 cm for a total boom width of 152 cm (Teejet Technologies, Springfield, IL, 62703). All field sites were disked and field cultivated prior to forming raised beds for planting. Herbicides labeled for use in conventional soybean were used throughout the season as well as row cultivation and hand weeding as needed. Each trial was furrow-irrigated approximately once in a week if less than 2.5 cm of rainfall occurred over a 7-day period using polytube irrigation equipment (Polytube™, Delta Plastics of the South, Stuttgart, AR, 72160). Grain was harvested from the center two rows of each 4-row plot using a small-plot combine (Almaco™, Nevada, IA, 50201) following maturity. Grain moisture was measured and corrected to 13% moisture. Relative yield was calculated for each cultivar by comparing the yield of treated and nontreated plots (treated yield/nontreated yield $*$ 100).

2.2. Cultivar Experiment. Field experiments were conducted in 2018 and 2019 at the Milo J. Shult Arkansas Agricultural Research and Extension Center in Fayetteville, AR (36.1°N, 94.1°W). The experiment evaluated tolerance of several commercial cultivars of non-dicamba-resistant soybean to a low rate of dicamba. For the split-plot arrangement, the whole-plot factor was cultivar and the split-plot factor was soybean growth stage at time of dicamba application. The cultivars chosen had a maturity group (MG) range from 4.6 to 5, which represents the optimum MG range for Arkansas [12]. The soil series for the trials in 2018 and 2019 was a Leaf silt loam (fine, mixed, active, thermic Typic Albaqualts), with the 2018 trial having 25% sand, 64% silt, and 11% clay, 1.67% organic matter (OM), and a pH of 6.0, and the 2019 trial having 17% sand, 74% silt, and 9% clay, 1.75% OM, and a pH of 6.6. The experiment included a *V*3 and an *R*1 timing for dicamba application with a total of 15 cultivars for evaluation in 2018 and 2019 (Table 1).

The experiments were planted on May 22 in 2018 and on May 27 in 2019. All soybean cultivars were planted at a 2.5 cm depth and a row spacing of 91 cm and at a seeding rate of 346,000 seed ha^{-1}. Each four-row plot was 6.1 m long with a 1.5 m alley. Dicamba (Clarity™, BASF Corporation, Research Triangle Park, NC) was applied at the *V*3 or *R*1 stages of growth with 2.2 g ae ha^{-1} of dicamba.

Table 1: Soybean cultivars, maturity groups, and traits as well as manufacturer and address.

Cultivars	Maturity group	Trait	Manufacturer	Location
DG4790	4.7	RoundupReady2®	Delta grow seed company, inc.	England, AR
DG4880	4.8	RoundupReady1®	Delta grow seed company, inc.	England, AR
DG4967	4.9	LibertyLink®	Delta grow seed company, inc.	England, AR
DG4977	4.9	LibertyLink® STS	Delta grow seed company, inc.	England, AR
Eagle Drewsoy	5.0	Conventional	Eagle seed company, inc.	Weiner, AR
GoSoy 49G16	4.9	RoundupReady1®	Stratton seed company	Stuttgart, AR
GoSoy 49L17	4.9	LibertyLink®	Stratton seed company	Stuttgart, AR
GoSoy 4912LL	4.9	LibertyLink®	Stratton seed company	Stuttgart, AR
GoSoy 50G17	5.0	RoundupReady1®	Stratton seed company	Stuttgart, AR
GoSoy 51C17	5.1	Conventional	Stratton seed company	Stuttgart, AR
Ireane	4.9	Conventional	Stratton seed company	Stuttgart, AR
Leland	5.0	Conventional	Stratton seed company	Stuttgart, AR
P47A76L	4.7	LibertyLink®	Pioneer	Johnston, IA
P4930 LL	4.9	LibertyLink®	Progeny Ag. Products	Wynne, AR
UA 5014C	5.0	Conventional	University of Arkansas	Fayetteville, AR

Visual estimates of injury were made 21 days after treatment (DAT) for each treatment application timing with a low dose of dicamba and ratings were conducted on a 0 to 100 scale, where 0 = no injury and 100 = plant death. At soybean maturity (*R*8), the height of five plants per plot was measured from the soil surface to the terminal in centimeters and reported relative to the nontreated for each cultivar. Possible differences in crop maturity caused by dicamba were evaluated by recording the date soybean in each plot reached maturity (*R*8) and reporting each relative to the corresponding nontreated. 2018 and 2019 data were analyzed and are presented separately; therefore, fixed effects include year. Injury was analyzed as a beta distribution while relative height, maturity date, and relative yield were analyzed as a gamma distribution using ANOVA with SAS 9.4 using PROC GLIMMIX [13]. Pairwise comparisons were computed when the global F-test was significant ($\alpha = 0.05$) and statistical differences between pairs were identified using compact letter display [14].

In 2019, Cercospora leaf blight (*Cercospora kikuchii*) (CLB) was observed on soybean at the end of the growing season in both the cultivar and planting date experiments in Fayetteville. Symptomology of CLB appeared more common on dicamba-treated than nontreated plots. Disease ratings for CLB were taken in both trials when soybean was at, or very near, the *R*6 growth stage. Ratings consisted of visible assessment of disease incidence per plot (how much of each plot showed CLB symptomology) on a scale from of 0 to 3, with 0 being no incidence and 3 being 67% or more of the plot showing symptoms. All ratings were analyzed as multinomial distributions using separation tests via contrast statements with the ratings analyzed as cumulative logit data in SAS 9.4 using PROC GLIMMIX [13]. Because contrast statements were used, obtaining letter separation data with a "least square means" statement in SAS was not possible.

2.3. Planting Date Experiment. A field experiment was conducted in 2019 at the Milo J. Shult Arkansas Agricultural Research and Extension Center in Fayetteville, AR. The late MG 4, glufosinate-resistant cultivar "Credenz CZ 4820LL" (BASF Corporation, Raleigh, NC) was planted at 346,000 seed ha^{-1} in four-row plots that were 6.1 meters in length with a 1.5-meter alley between replications and a row spacing of 91. The whole-plot factor was planting date (mid-April, mid-May, mid-June, and mid-July) and the split-plot factor was growth stage at the application of dicamba (Xtendimax™ herbicide, Bayer CropScience, St. Louis, MO) (none, *V*3, *R*1, and *V*3 followed by *R*1). Actual planting dates were April 11, May 15, June 13, and July 15.

Visual estimates of injury were made at 14, 21, and 28 days after treatment (DAT) for each treatment application timing with a low dose of dicamba and ratings were conducted on a 0 to 100 scale, where 0 = no injury and 100 = plant death. Injury ratings were analyzed as a beta distribution in a repeated measures analysis using the first order autoregressive (AR [1]) covariance structure. Possible differences in crop maturity caused by dicamba were evaluated by recording the date soybean in each plot reached maturity (*R*8) and reporting each relative to the nontreated check within each planting date. Yield data were taken at the harvest and made relative to the nontreated within each planting date. The effect of replication was included as a random effect while the effects of planting date, growth stage at application, and the interaction of each were analyzed as fixed effects. Injury ratings were analyzed as a beta distribution, while maturity date and relative yield were analyzed as gamma distributions using ANOVA with SAS 9.4 using PROC GLIMMIX 13] with means separated using Fisher's protected LSD ($\alpha = 0.05$).

3. Results and Discussion

3.1. Cultivar Experiment. Treatment of soybean with a low dose of dicamba did not negatively affect soybean maturity in either year, and so it is not discussed below (Table 2).

3.1.1. Injury. A significant main effect of cultivar ($P = 0.0005$) and of application timing ($P < 0.0001$) occurred for injury in 2018; in 2019, there was a significant interaction between cultivar and application timing

Table 2: Effects of cultivar and application timing for injury, relative height, relative maturity, and relative yield (relative to nontreated) of soybean in at Fayetteville, AR, in 2018 and 2019.

Factors	2018				2019			
	Injury (%)	Height (%)	Maturity	Yield (%)	Injury (%)	Height (%)	Maturity	Yield (%)
	P-values							
Cultivar	0.0005	0.9972	0.1049	0.0867	0.1501	0.7275	0.5408	0.0523
Application timing	<0.0001	0.0185	0.8555	0.6234	<0.0001	0.0216	0.2176	0.0520
Cultivar ∗ application timing	0.0691	0.8851	0.1062	0.7974	<0.0001	0.7459	0.2622	0.2131

[a] *P*-values less than 0.1 considered significant as shown in bold.

Figure 1: Visual estimates of soybean injury at 21 days after treatment according to the main effects of application timing and cultivar for the cultivar experiment conducted in Fayetteville, AR in 2018. The occurrence of a greater injury for the main effect of application timing, according to multiple comparisons analysis ($\alpha = 0.05$), is denoted by an asterisk over the *R*1 treatment. Differences among the main effect of cultivar are denoted by uppercase letters. Treatments not sharing any uppercase letter are significantly different according to multiple comparison analysis $\alpha = 0.05$ [14].

($P < 0.0001$) (Table 2). In 2018, injury of *V*3 soybean was lower than injury of R1 soybean, an occurrence that is contrary to most of the literature (Figure 1). Soybean in vegetative growth stages typically respond to dicamba treatments by manifesting greater symptomology or a more visible injury than soybean treated with dicamba at reproductive stages [15–18]. The injury difference between the *V*3 and *R*1 applied soybean in 2018 versus in 2019 is attributed to a precipitation event totaling 0.45 cm that occurred approximately 4 hours after the *V*3 application in 2018, reducing dicamba absorption due to wash-off and injury at this timing. The rainfall period for a post-emergence application of dicamba is 4 hours.

Only “Eagle DrewSoy” (36% injury) and “Leland” (33% injury) were among the least injured cultivars, (within the lowest letters indicating significance based on the least significant difference) in 2018 (Figure 1). Injury data collected in 2019 revealed a significant interaction of growth stage and cultivar; however, injury of *V*3 soybean was higher than in 2018 as there was no precipitation event following either application timing, and there was less total variation in injury for the experiment compared to 2018 (Table 2; Figures 1 and 2).

In 2019, every cultivar treated at *V*3 had significantly higher injury than cultivars treated at *R*1 (Figure 2). Due to the decreased range in observed injury, there were more cultivars within each pairwise comparison with a total of 9 cultivars having a similar level of injury among the lowest letter separation in 2019 (Figure 2). Among these 9 cultivars, all treated at *R*1, only “Eagle DrewSoy” (55% injury) was among the least injured cultivars in 2018 (Figure 1). These findings suggest that “Eagle DrewSoy” manifested less visible injury across years regardless of vegetative or reproductive application timing, and that genetic factors may be less

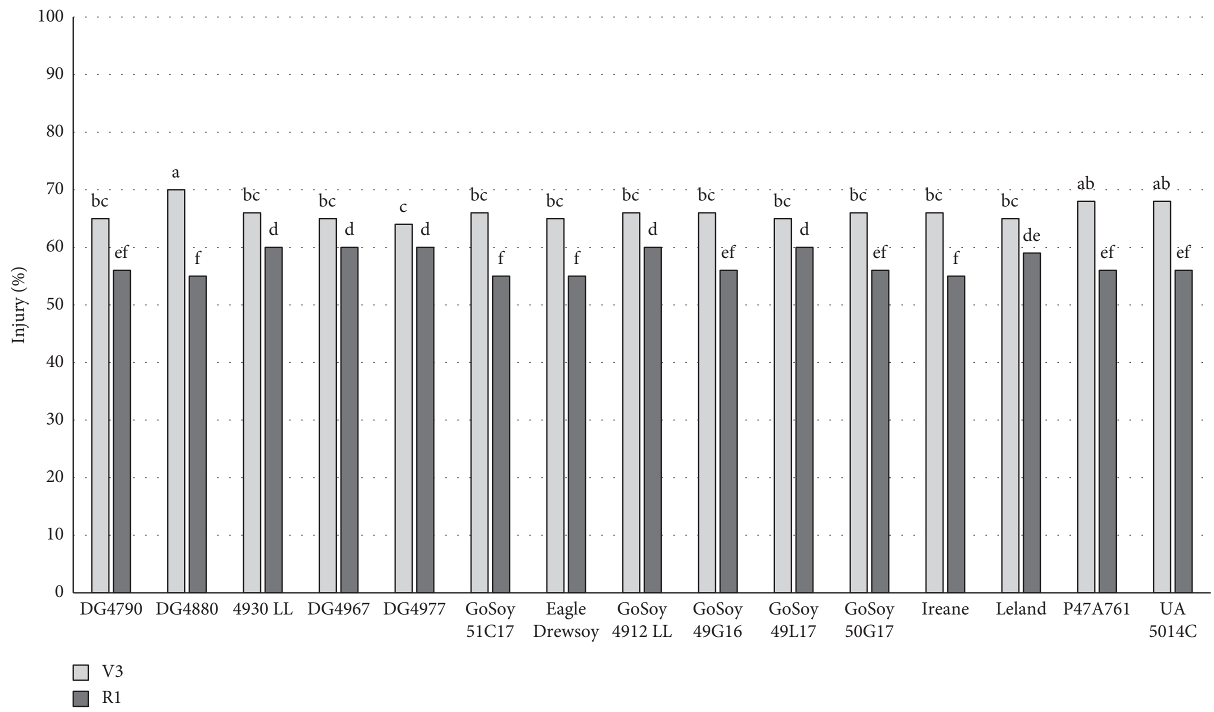


Figure 2: Visual estimates of soybean injury at 21 days after treatment according to the interaction of cultivar and application timing for the cultivar experiment conducted in Fayetteville, AR in 2019. Treatments not sharing any lowercase letter are significantly different according to multiple comparison analysis $\alpha = 0.05$ [14].

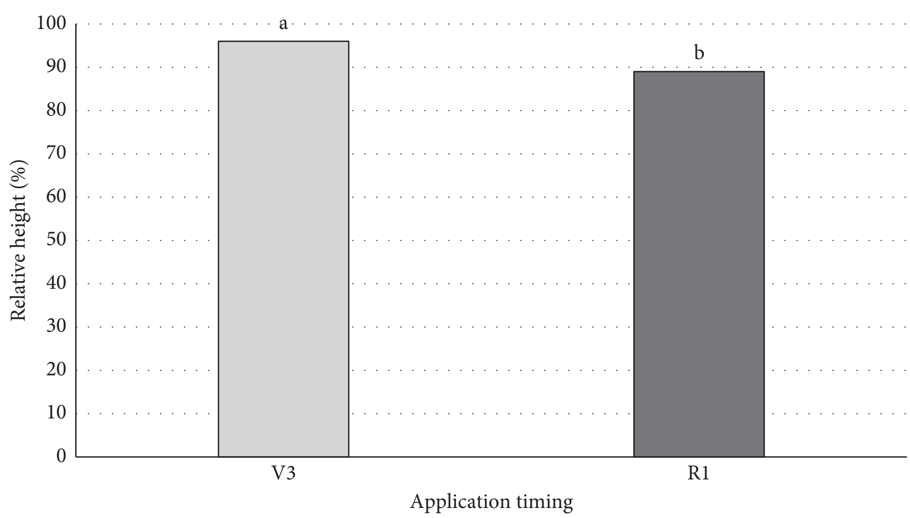


Figure 3: Soybean heights collected at maturity and made relative to the nontreated check according to the main effect of application timing for the cultivar experiment conducted in Fayetteville, AR, in 2018. Treatments not sharing any lowercase letter are significantly different according to multiple comparison analysis $\alpha = 0.05$ [14].

important than environmental factors in dictating the extent of injury observed on most of the soybean cultivars.

3.1.2. Relative Height. The relative height of soybean at harvest was significantly affected by application timing in both 2018 (P = 0.0185) and 2019 (P = 0.0216) (Table 2). For 2018, relative height of soybean treated at $V3$ (96%) was greater than soybean treated at $R1$ (89%; Figure 3). The opposite was true in 2019, where relative height of $V3$-treated (86%) was less than $R1$-treated soybean (93%) (Figure 4). Typically, the height of soybean is reduced more by vegetative dicamba applications as opposed to reproductive applications [18]. The difference in relative height between years is attributed to a decrease in herbicide efficacy due to the precipitation event after the $V3$-application in 2018 that also impacted soybean injury (data not shown). Interestingly, there was not a significant cultivar effect for height.

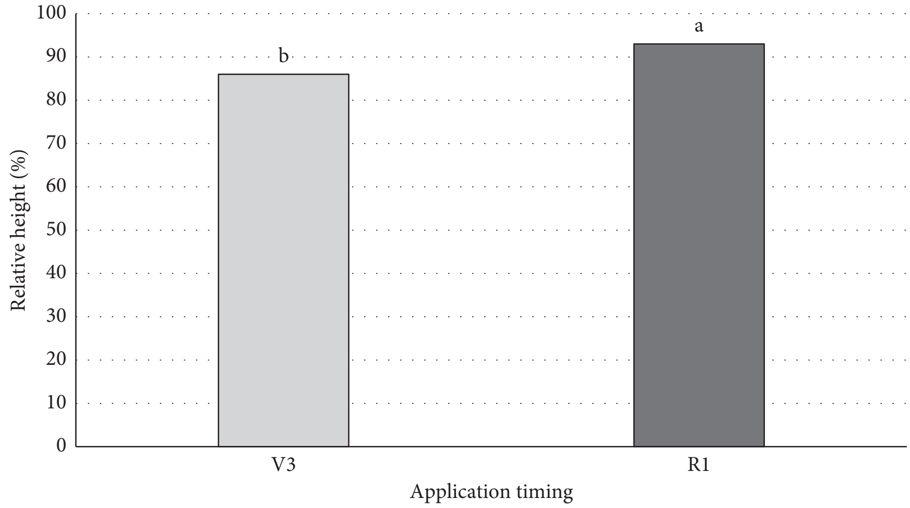


Figure 4: Soybean heights collected at maturity and made relative to the nontreated check according to the main effect of application timing for the cultivar experiment conducted in Fayetteville, AR, in 2019. Treatments not sharing any lowercase letter are significantly different according to multiple comparison analysis $\alpha = 0.05$ [14].

3.1.3. Relative Yield. The effect of cultivar was not significant for relative yield in 2018 ($P = 0.086$) or 2019 ($P = 0.0523$), nor were there any other significant effects (Table 2). The absence of a cultivar-by-application timing interaction indicates that there were no differences in response among cultivars for yield at the application timings and the dicamba rate tested. A higher rate of dicamba could have led to differences among cultivars, if there truly were potential differences in the ability of cultivars to recover from dicamba exposure. In future experiments, multiple applications of dicamba should also be considered to elicit possible relative yield differences among cultivars.

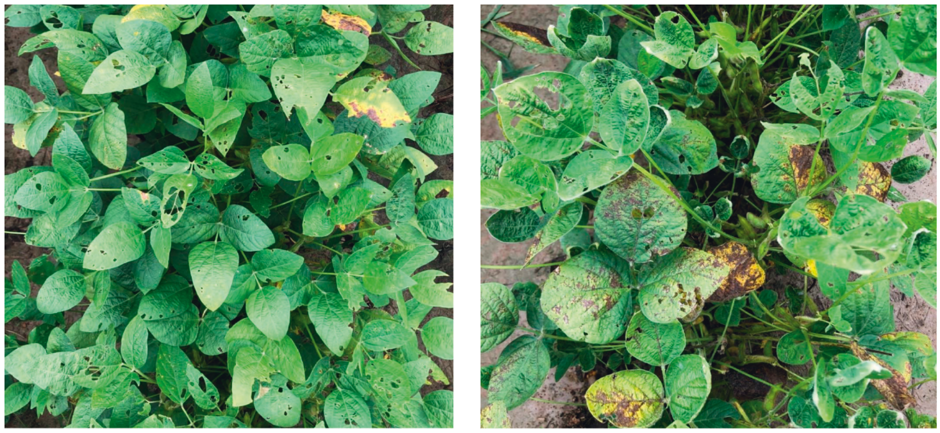
The purpose of this study was to determine if soybean cultivars with enhanced tolerance to dicamba exist and if tolerance is consistent across application timings. Findings indicate that the relative yield of soybean cultivars were not affected differently by a low-dose dicamba application at the rate and application timings of this study. Repeating this experiment after adjusting parameters, such as the number of cultivars included, or including additional application timings or rates of dicamba, could provide different results, especially considering that the *P*-values of this experiment were close to an alpha value of 0.05. In other research evaluating over 300 soybean genotypes for differences in soybean sensitivity to dicamba, consistency in ranking of cultivar tolerance to the herbicide was seldom observed across environments (L. C. Purcell and J. K. Norsworthy, personal communication).

3.1.4. Cercospora Leaf Blight. Cercospora leaf blight was observed on the cultivar experiment in 2019. A significant main effect of application timing occurred with incidence of CLB ($P < 0.0001$) (data not shown). Cercospora leaf blight infected a higher percentage of plots exposed to dicamba at the *R*1 growth stage than either a *V*3 exposure or nontreated (Figure 5). There were 44 incidence ratings of 4 among the *R*1-treated soybean plots compared to only 7 among *V*3-treated plots and no incidence on any nontreated cultivar. Despite varying incidence of CLB by application timing, there was no effect of application timing to relative yield (Table 2), therefore, it appears that CLB had no effect on yield.

3.2. Planting Date Experiment. There was a significant three-way interaction among planting date, application timing, and rating date for injury (Table 3). Considering a high number of significant interactions, only those most relevant to planting date are discussed.

3.2.1. Injury. Ultimately, soybean exposed to dicamba at the *V*3 stage experienced a delay in maximum injury expression as planting dates became later. Among soybean planted in April and May, the greatest injury was seen at 14 DAT (47 and 51%, respectively; Figure 6). In June, injury did not differ between 14 (44%) and 21 DAT (39%), and by July, the greatest injury was observed at 21 DAT (50%) (Figure 6). The less-than-ideal conditions caused by later planting dates (June and July) delayed maximum injury expression of the *V*3-treated soybean to 21 and 28 DAT, versus April and May significantly reaching maximum visible injury at the earlier 14 DAT rating date. The conditions that late-planted soybean encounter include the effect of a long photoperiod [7] and high heat, causing abbreviated vegetative and reproductive growth stages [6], reducing soybean photosynthesis and growth [8], and often decreasing plant size at each application stage versus soybean planted earlier [11].

Similar to soybean treated with dicamba at *V*3, the *R*1-treated soybean experienced a delay of maximum injury expression across rating date as planting dates became later. Unlike the *V*3 treatment, the greatest injury among earlier planting dates was noted among the latest rating dates. Among the April planting date, the highest injury was observed at 28 DAT (49%), whereas by May injury was not



(a) (b)

Figure 5: (a) Image of Cercospora leaf blight (*Cercospora kikuchii*) on a soybean plot treated with dicamba at the *V*3 application timing versus (b) a plot treated with dicamba applied at the *R*1 application timing. Images taken while soybean were in the *R*6 growth stage.

Table 3: Effects of planting date, application timing, and rating date to injury analyzed as a repeated measures analysis for the planting date experiment conducted in Fayetteville and Stuttgart, AR, in 2019.

Factors	Injury[a]
	P-values
Planting date	0.0454
Timing	<0.0001
Rating date	0.0179
Planting date ∗ timing	<0.0001
Planting date ∗ rating date	<0.0001
Timing ∗ rating date	<0.0001
Planting date ∗ timing ∗ rating date	<0.0001

[a]*P*-values at or smaller than 0.05 level considered significant.

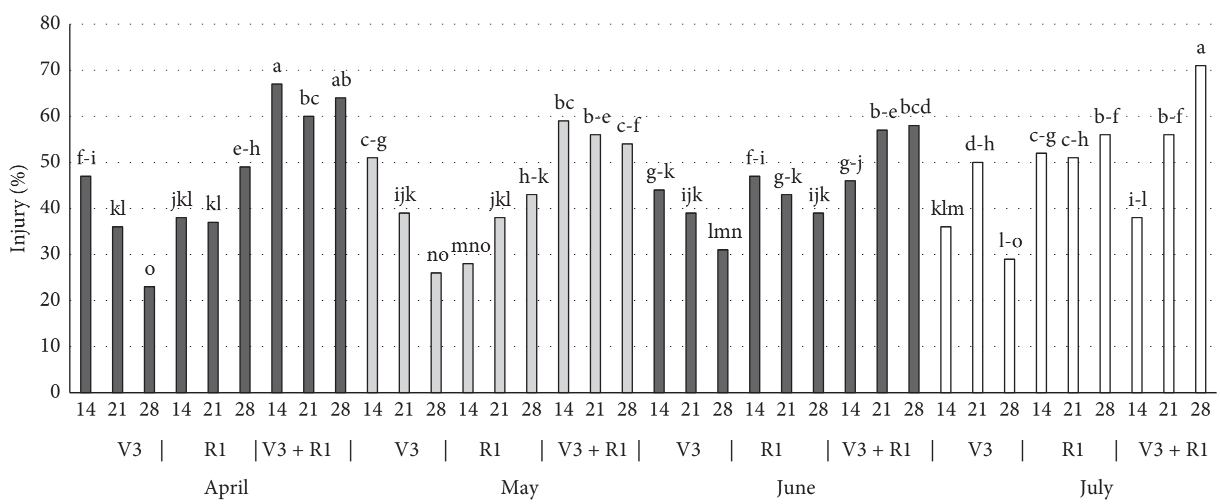


Figure 6: Visual estimates of soybean injury at 14, 21, and 28 days after a low-dose dicamba exposure at two growth stages (*V*3 and *R*1) for April, May, June, and July planting dates in Fayetteville, AR, in 2019. Treatments not sharing any lowercase letter are significantly different according to multiple comparison analysis $\alpha = 0.05$ [14].

different between 21 and 28 DAT (38 and 43%, respectively (Figure 6). By June and July, injury did not differ significantly across rating date (Figure 5); however, among the July planting date, the injury at each rating date (52, 51, and 56% for 14, 21, and 28 DAT, respectively) was numerically greater than the injury of *R*1-treated soybean at any other rating date within other planting dates (Figure 6). Similar to the *V*3 treatment, the increase in injury of *R*1-treated soybean for

Table 4: Effects of planting date and application timing to maturity date and relative yield for the planting date experiment conducted at Fayetteville and Stuttgart, AR in 2019.

Factors	Maturity date	Relative yield
	P-values	
Planting date	0.0196	<0.0001
Application timing	0.6790	<0.0001
Planting date ∗ application timing	0.7911	0.2522

[a]*P*-values at or smaller than 0.05 level considered significant as shown in bold.

Table 5: Days delay until soybean maturity relative to the nontreated check averaged over a low-dose dicamba exposure at *V*3, *R*1, and *V*3 followed by *R*1 stage of soybean.

Planting date	Soybean maturity delay[a]
April	6.0 a
May	2.4 b
June	1.6 b
July	2.4 b

[a]Means within a row followed by the same lowercase letter are not different according to multiple comparison analysis $\alpha = 0.05$ [14].

July at 14, 21, and 28 DAT is attributed to the effect of the sub-par conditions at this late planting date compared to earlier plantings [6]. The conditions at the later planting date also led to a smaller plant size, due to shorter plant height, and fewer nodes [5, 11], allowing for a greater visible injury manifestation at the remaining nodes for this planting date.

Injury of soybean treated sequentially—at *V*3 followed by *R*1—saw a gradual postponement of symptoms, with the greatest injury at later rating dates (21 and 28 DAT) among the later planting dates (Figure 6). At 14 DAT of the sequential application, a combination of the effects of the *V*3 treatment, at which the greatest injury was expressed at earlier rating dates, and the *R*1 treatment, at which the greatest injury at later rating dates, occurs. This combination manifests as no significant difference in injury of the sequential treatment for April and May (Figure 6); however, at later planting dates, the maximum injury expression is delayed. This trend is similar to the delayed maximum injury seen among *V*3-treated soybean. By June, injury of the sequentially-treated soybean at 14 DAT (47%) was significantly lower than injury at 21 and 28 DAT (57 and 58%, respectively; Figure 5). For soybean planted in July, injury of the sequentially-treated soybean significantly increased with each subsequent rating date (38, 56, and 71% at 14, 21, and 28 DAT, respectively; Figure 6).

The trend observed among the sequentially treated soybean is attributed to less-than-ideal conditions at the later planting dates that caused increased soybean injury and a delay of visible injury manifestation as the planting date becomes later. As mentioned, late planting leads to a smaller plant size at application [11] and a greater herbicide efficacy following application relative to earlier plantings, also extending the activity of dicamba within the plant as the herbicide metabolizes more slowly in these smaller plants. This would result in a greater visible injury over time, thus explaining the greater injury at later rating dates among June and July plantings.

Table 6: Relative yield of soybean at four planting dates averaged over a low-dose dicamba exposure at *V*3, *R*1, and *V*3 followed by *R*1 stage of soybean.

Planting date	Relative yield (%)[a]
April	103 a
May	101 a
June	80 a
July	39 b

[a]Means within a row followed by the same lowercase letter are not different according to multiple comparison analysis $\alpha = 0.05$ [14]. Yield of the nontreated check reported in $kg \cdot ha^{-1}$ by month as follows: 3670, 3550, 5130, 3420 for April, May, June, and July, respectively.

3.2.2. Maturity. Soybean maturity date was significantly affected by the main effect of planting date (Table 4). Within the April planting date soybean treated with dicamba matured 6 days later than the nontreated, and significantly later than soybean treated with dicamba at any other planting date (Table 5).

3.2.3. Relative Yield. Only the main effects of planting date and application timing affected relative yield (Table 4). The April, May, and June (103, 101, and 80% relative yield, respectively) planting dates were not different, but the July date had significantly lower relative yield at 39% of the nontreated (Table 6). Planting at later dates does commonly result in lower yields versus earlier, more optimal, planting dates [7, 8]. Optimal planting dates of soybean with maturity groups of V to VIII is May through early June [9], with yield rapidly declining for soybean planted after these optimal dates [10]. In this experiment, the yield reduction was primarily due to the later planting date causes shorter intervals for each growth stage relative to earlier planting dates [6]. Additionally, the latest planting date had reduced total biomass present at the time of dicamba application, causing greater injury to the smaller plants and negating much of the recovery potential of the soybean plant. Comparing application timings, only soybean treated at the *V*3 timing yielded similar to the nontreated, whereas soybean in plots treated at both *R*1 and the *V*3 plus *R*1 stages yield only 70 and 56% of the nontreated, respectively (data not shown). Greater yield loss among soybean exposed to dicamba at reproductive stages as compared to vegetative stages is common [16].

3.3. Practical Implications. The results of this research help determine the effect of multiple cultivars and multiple planting dates to non-dicamba-resistant soybean when injured by dicamba at a low rate, such as supplied by off-target movement. According to the results of the cultivar experiment, the cultivar "Eagle DrewSoy" exhibited low visible injury compared to other cultivars tested across both year and location; however, no cultivar exhibited yield differences. Further research with more cultivars and application timings or different rates of dicamba could provide different results. Identification of dicamba-tolerant cultivars could lead to the isolation of the gene(s) responsible and could lead to the production of soybean cultivars with enhanced tolerance to dicamba. Within the planting date experiment, soybean treated with a low-dose of dicamba following the July planting experienced a greater reduction in yield compared to other planting dates. This indicates that dicamba injury to late-planted soybean causes a greater yield loss compared to soybean exposed to dicamba at optimum planting dates. In addition, CLB was noted in both experiments in Fayetteville of 2019, with greater incidence among dicamba-treated soybean; however, it is unlikely that yield was affected by CLB.

Data Availability

Raw and underlying data from the original studies contained and summarized in the submitted document are found in the paper and/or digital form at the University of Arkansas CROP lab building (1354, W. Altheimer Dr., Fayetteville, AR 72704). All available data are accessible contacting the authors.

Conflicts of Interest

No conflicts of interest have been declared by the authors.

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